Claims

We claim:

1. A heat exchanger comprising:
   a. a manifold layer having a first plurality of openings for providing a cooling material to the heat exchanger and a second plurality of openings for removing the cooling material from the heat exchanger; and
   b. an interface layer coupled to the manifold layer, the interface layer having a plurality of routes that each extends from one of the first plurality of openings and terminates at a corresponding one of the second plurality of openings, the route for carrying the cooling material, the plurality of routes each substantially contained in a plane non-parallel to a heat-exchanging plane.

2. The heat exchanger of claim 1, wherein each route is adjacent to another route, whereby heat can be exchanged between cooling material circulating within adjacent routes.

3. The heat exchanger of claim 2, wherein each route extends from one of the first plurality of openings toward the heat-exchanging plane and then turns to extend away from the heat-exchanging plane toward a corresponding one of the second plurality of openings.

4. The heat exchanger of claim 3, wherein each route is substantially U shaped.

5. The heat exchanger of claim 3, wherein after a route extends from one of the first plurality of openings and before the route extends toward one of the second plurality of openings, the route extends substantially parallel to the heat-exchanging plane.

6. The heat exchanger of claim 1, wherein the interface layer comprises a structural material having a thermal conductivity of at least approximately 20 W/m-K.

7. The heat exchanger of claim 6, wherein the structural material comprises a semiconductor.

8. The heat exchanger of claim 6, wherein the structural material comprises a metal.

9. The heat exchanger of claim 6, wherein the structural material comprises a porous material that defines the plurality of routes.

10. The heat exchanger of claim 9, wherein the porous material comprises a porous metal.

11. The heat exchanger of claim 9, wherein the porous material comprises a silicon foam.

12. The heat exchanger of claim 6, wherein the structural material exhibits anisotropic etching.

13. The heat exchanger of claim 12, wherein the structural material that exhibits anisotropic etching is selected from the group consisting of micro-scale copper tubing and copper filaments.

14. The heat exchanger of claim 6, wherein the structural material comprises a composite of materials.

15. The heat exchanger of claim 1, wherein the cooling material comprises a liquid.

16. The heat exchanger of claim 15, wherein the liquid comprises water.

17. The heat exchanger of claim 1, wherein the cooling material comprises a vapor.

18. The heat exchanger of claim 1, wherein the cooling material comprises a gas.

19. The heat exchanger of claim 1, wherein the cooling material is air.

20. The heat exchanger of claim 1, wherein the first plurality of openings and the second plurality of openings lie substantially in a single plane.

21. The heat exchanger of claim 1, further comprising a heat insulator between the first plurality of openings and the second plurality of openings.

22. The heat exchanger of claim 21, wherein the heat insulator comprises an air gap.

23. The heat exchanger of claim 21, wherein the heat insulator comprises a vacuum gap.

24. The heat exchanger of claim 21, wherein the heat insulator comprises an insulating material having a thermal conductivity of approximately 5 W/m-K or less.

25. The heat exchanger of claim 1, wherein a cross-sectional dimension of a route changes as it extends from one of the first plurality of openings to one of a second plurality of openings.

26. The heat exchanger of claim 25, wherein a cross-sectional dimension of a route increases uniformly as it extends from one of the first plurality of openings to a corresponding one of the second plurality of openings.

27. The heat exchanger of claim 1, further comprising a heat-generating device coupled to a bottom surface of the interface layer.

28. The heat exchanger of claim 27, wherein the heat-generating device is formed integrally with the bottom surface of the interface layer.

29. The heat exchanger of claim 27, wherein the heat-generating device is a semiconductor device.

30. The heat exchanger of claim 1, wherein each route comprises a channel.

31. The heat exchanger of claim 1, wherein the plurality of routes is defined by a plurality of pin fins.

32. The heat exchanger of claim 31, wherein the plurality of pin fins are positioned cross-wise to the plurality of routes.

33. The heat exchanger of claim 1, further comprising a pump coupled to the first plurality of openings.

34. The heat exchanger of claim 1, wherein the manifold layer and the interface layer form a monolithic device.

35. A method of forming a heat exchanger comprising:
  a. forming a manifold layer having a first plurality of openings for providing a cooling material to the heat exchanger and a second plurality of openings for removing the cooling material from the heat exchanger; and
  b. forming an interface layer coupled to the manifold layer, the interface layer having a plurality of routes that each extends from one of the first plurality of openings and terminates at a corresponding one of the second plurality of openings, the route for carrying the cooling material, the plurality of routes each substantially contained in a plane non-parallel to a heat-exchanging plane.

36. The method of claim 35, wherein each route is adjacent to another route.

37. The method of claim 35, wherein each route extends from one of the first plurality of openings toward the heat-exchanging plane and then turns to extend away from the heat-exchanging plane toward a corresponding one of the second plurality of openings.

38. The method of claim 37, wherein each route is substantially U shaped.

39. The method of claim 37, wherein after a route extends from one of the first plurality of openings and before the route extends toward one of the second plurality of openings, the route extends substantially parallel to the heat-exchanging plane.

40. The method of claim 35, wherein the interface layer comprises a structural material having a thermal conductivity of at least approximately 20 W/m-K.

41. The method of claim 40, wherein the structural material comprises a semiconductor.

42. The method of claim 40, wherein the structural material comprises a metal.

43. The method of claim 40, wherein the structural material comprises a porous material defining the plurality of routes.

44. The method of claim 43, wherein the porous material comprises a porous metal.

45. The method of claim 43, wherein the porous material comprises a silicon foam.

46. The method of claim 40, wherein the structural material exhibits anisotropic etching.

47. The method of claim 46, wherein the structural material exhibiting anisotropic etching is selected from the group consisting of micro-scale copper tubing and copper filaments.

48. The method of claim 40, wherein the structural material comprises a composite of materials.

49. The method of claim 35, wherein the first plurality of openings and the second plurality of openings lie substantially in a single plane.

50. The method of claim 35, further comprising forming a heat insulator between the first plurality of openings and the second plurality of openings.

51. The method of claim 50, wherein the heat insulator comprises an air gap.

52. The method of claim 50, wherein the heat insulator comprises a vacuum gap.

53. The method of claim 50, wherein the heat insulator comprises a material having a thermal conductivity of approximately 5 W/m-K or less.

54. The method of claim 35, wherein a cross-sectional dimension of a route changes as it extends from one of the first plurality of openings to a corresponding one of the second plurality of openings.

55. The method of claim 54, wherein a cross-sectional dimension of a route increases uniformly as it extends from one of the first plurality of openings to a corresponding one of a second plurality of openings.

56. The method of claim 35, further comprising coupling a heat-generating device to a bottom surface of the interface layer.

57. The method of claim 56, wherein coupling a heat-generating device to a bottom surface of the interface layer comprises integrally forming the heat-generating device to the bottom surface of the interface layer.

58. The method of claim 57, wherein the heat-generating device is a semiconductor device.

59. The method of claim 35, wherein each route comprises a channel.

60. The method of claim 35, wherein each route is defined by a plurality of pin fins.

61. The method of claim 60, wherein the plurality of pin fins are positioned crosswise to the plurality of routes.

62. The method of claim 35, wherein the manifold layer and the interface layer form a monolithic device.

63. The method of claim 35, wherein the step of forming an interface layer comprises patterning a semiconductor device and etching the patterned semiconductor device to form the interface layer.

64. The method of claim 35, wherein the step of forming an interface layer comprises stamping a sheet of metal in the shape of the plurality of routes.

65. The method of claim 35, wherein the step of forming an interface layer comprises injection molding a metal in the shape of the plurality of routes.

66. A method of cooling a device comprising transmitting a cooling material from an inlet manifold, through a plurality of stacked routes positioned over the device, and to an outlet manifold.

67. The method of claim 66, wherein the stacked routes comprise a structural material having a thermal conductivity of at least approximately 20 W/m-K.

68. The method of claim 67, wherein the structural material comprises a semiconductor.

69. The method of claim 67, wherein the structural material comprises a metal.

70. The method of claim 67, wherein the structural material comprises a porous material that defines the plurality of stacked routes.

71. The method of claim 70, wherein the porous material comprises a porous metal.

72. The method of claim 70, wherein the porous material comprises a silicon foam.

73. The method of claim 67, wherein the structural material exhibits anisotropic etching.

74. The method of claim 73, wherein the structural material exhibiting anisotropic etching comprises a material selected from the group consisting of micro-scale copper tubing and copper filaments.

75. The method of claim 67, wherein the structural material comprises a composite of materials.

76. The method of claim 66, wherein the plurality of stacked routes comprises pin fins.

77. The method of claim 66, wherein the cooling material comprises a liquid.

78. The method of claim 77, wherein the liquid is water.

79. The method of claim 66, wherein the cooling material comprises a vapor.

80. The method of claim 66, wherein the cooling material comprises a gas.

81. The method of claim 66, wherein the cooling material is air.